

Revisiting texture 5 zero quark mass matrices

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Abstract

The question of viability of texture 5 zero Fritzsch-like quark mass matrices are examined in the context of the latest quark mixing data

It has been shown that all possible combinations of texture 6 zero quark mass matrices, Fritzsch-like as well as non Fritzsch-like are already ruled out [1],[2]. Similarly, all possible combinations of hermitian texture 5 zero quark mass matrices are also ruled out except for the case when M_U is texture 3 zero type and M_D is texture 2 zero type [2]. The purpose of the present work is to examine the implications of recently refined data on texture specific quark mass matrices. The plan of paper is as follows. In Section I we discuss the essentials of formalism of texture 5 zero quark mass matrices and in Section II we discuss the inputs used for analyses. In Section III we present discussion of analyses and in Section IV we summarize our conclusions.

1 Texture specific mass matrix and CKM matrix

For the sake of readability, we underline some of the essentials of the methodology leading to the construction of the V_{CKM} . To define the various texture specific cases considered here, we present the typical Fritzsch like texture specific hermitian quark mass matrices, for example,

$$M_U = \begin{pmatrix} 0 & A_U & 0 \\ A_U^* & D_U & B_U \\ 0 & B_U^* & C_U \end{pmatrix}, \quad M_D = \begin{pmatrix} 0 & A_D & 0 \\ A_D^* & D_D & B_D \\ 0 & B_D^* & C_D \end{pmatrix}, \quad (1)$$

where M_U and M_D correspond to up and down mass matrices respectively, A and B are complex elements and C is a real element of the mass matrix. It may be

noted that each of the above matrix is texture 2 zero type with $A_k = |A_k|e^{i\alpha_k}$ and $B_k = |B_k|e^{i\beta_k}$, where $k = U, D$. The texture specific Fritzsch-like mass matrices discussed above, can be exactly diagonalized and the corresponding V_{ckm} can be constructed from these. To illustrate the procedure as well as to facilitate discussion, we detail the construction of V_{ckm} . Further, we define $\phi_1 = \alpha_U - \alpha_D$, $\phi_2 = \beta_U - \beta_D$. The complex matrix M_i ($i = U, D$) can be expressed as $M_i = P_i^\dagger M_i^r P_i$, where $P_i = \text{diag}(e^{-i\alpha_i}, 1, e^{i\beta_i})$ and the real matrix M_i^r is

$$M_i^r = \begin{pmatrix} 0 & |A_i| & 0 \\ |A_i| & D_i & |B_i| \\ 0 & |B_i| & C_i \end{pmatrix}. \quad (2)$$

The M_i^r can be diagonalized by the orthogonal transformation, for example,

$$M_i^{\text{diag}} = O_i^T M_i^r O_i \equiv O_i^T P_i M_i P_i^\dagger O_i, \quad (3)$$

where

$$M_i^{\text{diag}} = \text{diag}(m_1, -m_2, m_3), \quad (4)$$

the subscripts 1, 2 and 3 refer respectively to u , c and t for the U sector and d , s and b for the D sector. It may be noted that the second mass eigen value is chosen with a negative sign to facilitate the construction of the diagonalizing transformation O_i , for the details in this regard we refer the reader to [1].

Using the invariants, $\text{tr}M_i^r$, $\text{tr}M_i^{r^2}$ and $\det M_i^r$, the values of the matrix elements $|A_i|$, $|B_i|$ and C_i can be expressed in terms of quark masses as

$$C_i = (m_1 - m_2 + m_3 - D_i), \quad (5)$$

$$|A_i| = (m_1 m_2 m_3 / C_i)^{1/2}, \quad (6)$$

$$|B_i| = [(m_3 - m_2 - D_i)(m_3 + m_1 - D_i)(m_2 - m_1 + D_i) / C_i]^{1/2}. \quad (7)$$

The details of the relationship between the mass matrices and the mixing matrix are given [1], for example,

$$V_{\text{CKM}} = O_U^T P_U P_D^\dagger O_D = V_U^\dagger V_D, \quad (8)$$

where the unitary matrices $V_U (= P_U^\dagger O_U)$ and $V_D (= P_D^\dagger O_D)$ are the diagonalizing matrices for the hermitian matrices M_U and M_D respectively.

2 Inputs used for analysis

For ready reference as well as to facilitate the discussion, the input quark masses at the m_Z scale [3] used in the analysis are given as

$$\begin{aligned} m_u &= 1.27_{-0.42}^{+0.50} \text{ MeV}, & m_d &= 2.90_{-1.19}^{+1.24} \text{ MeV}, & m_s &= 55_{-15}^{+16} \text{ MeV}, \\ m_c &= 0.619_{-0.084}^{+0.084} \text{ GeV}, & m_b &= 2.89_{-0.09}^{+0.09} \text{ GeV}, & m_t &= 171.1_{-3.0}^{+3.0} \text{ GeV}. \end{aligned} \quad (9)$$

The light quark masses m_u , m_d and m_s have been further constrained by using the mass ratios [4]. For the purpose of our calculations, we are giving full variation to

phases ϕ_1 and ϕ_2 from 0 to 2π . We have assumed the condition of naturalness of mass matrices implying that D_U and D_D be restricted in the ranges $(0.0464-0.4870) m_t$ and $(0.0276-0.4448) m_b$ respectively. While carrying out the analyses, we first attempt to reproduce V_{us} , V_{ub} and V_{cb} corresponding respectively to s_{12} , s_{23} and s_{13} as well as CP asymmetry parameter $\text{Sin}2\beta$. It may be mentioned that for our analysis, we have considered a wide range of $V_{ub} = (4.15 \pm 0.49) \times 10^{-3}$, which includes both its exclusive and inclusive values.

3 Results and discussion

To begin with, we first discuss the two cases of texture 5 zero Fritzsch-like mass matrices which can be obtained from equation (1) by taking either $D_U = 0$ and $D_D \neq 0$ or $D_U \neq 0$ and $D_D = 0$. To check the viability of these 2 cases of texture 5 zero quark mass matrices, we attempt to reproduce the CKM matrix. However, we find out that out of the two cases, only one possibility $D_U=0$ case has limited viability, while the other case seems to be ruled out. For this purpose, by giving full variation to phases ϕ_1 and ϕ_2 as well as to D_U or D_D and by including the constraints of only $|V_{us}|$ and $|V_{ub}|$, we have made an attempt to calculate the CKM matrix element V_{td} . To this end, in Figures (1a) and (1b) we have plotted the CKM

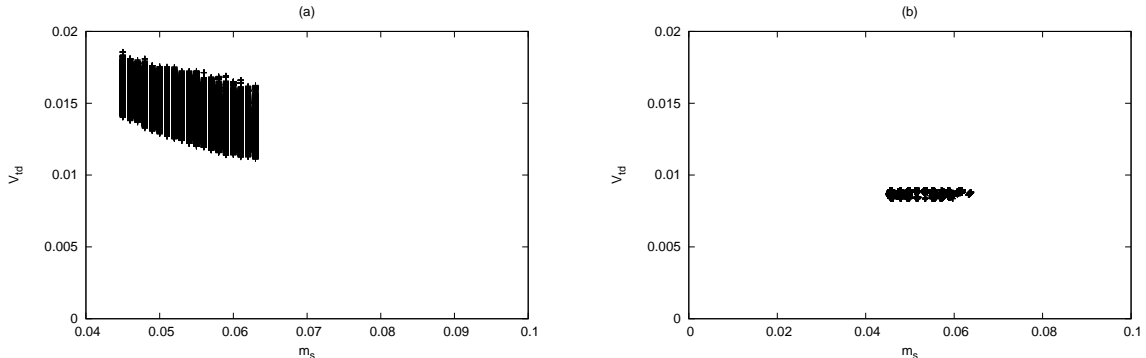


Figure 1: Plot showing variation of V_{td} with the strange quark mass m_s for the two cases of texture 5 quark zero mass matrices (a) $D_D=0$ case (b) $D_U=0$ case.

matrix element V_{td} against the strange quark mass for $D_D=0$ and $D_U=0$ case of texture 5 zero mass matrices respectively. From Figure (1a) it is immediately clear that for all values of m_s considered here, the range of V_{td} is much higher than the values quoted by PDG [5], whereas, from (1b) one finds that V_{td} can be obtained within the allowed range. However, in case the higher values of m_s than the one considered here are used then this case is also ruled out.

4 Summary and conclusions

To summarize, we have analyzed texture 5 zero quark mass matrices keeping in mind the recently refined data. Using the latest inputs regarding masses and mixing

parameters, we find that the texture 5 zero $D_D=0$ and $D_U \neq 0$ case is completely ruled out whereas the other texture 5 zero $D_U=0$ and $D_D \neq 0$ case has limited viability depending upon the mass of strange quark m_s used.

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